NASA TT F-11,138

STUDY OF SLEEP CHARACTERISTICS UNDER CONDITIONS OF SIMULATED MANNED SPACE FLIGHT

V.I.Myasnikov

Translation of "Izucheniye osobennostey sna v usloviyakh, modeliruyushchikh kosmicheskiy polet". Kosmicheskaya Biologiya i Meditsina, Vol.I, No.2, pp.59-63, 1967.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 AUGUST 1967

STUDY OF SLEEP CHARACTERISTICS UNDER CONDITIONS OF SIMULATED MANNED SPACE FLIGHT

/59*

V.I.Myasnikov

ABSTRACT. To determine factors for protecting spacecraft crews on long-duration missions from environmental hazards and physiological stress, characteristics of sleep patterns in their relation to adaptation and resistance of the organism, were studied. Data are given on reactions to protracted exposure to noise, angular acceleration, and isolation in their effect on sleep. Impairment of sleep included difficult wake-sleep transition, semiwakefulness, etc. Correlation of sleep with functional changes is demonstrated with respect to motion sickness and impaired acoustic adaptation. The significance of differential diagnosis of somnolent, precollaptoid, and fatigue states is emphasized.

The successful solution of a number of medicobiological problems, posed by the practice of space studies (protection of the body from unfavorable factors of flight and space environment; assuring maintenance of high work capability; rational layout of the work-and-rest cycle; planning of medical supervision, selection, and training of astronauts, etc.), largely depends on a detailed and comprehensive study of sleep as one of the forms of rest, a state which plays the role of a natural-physiological protection and is directly related to adaptation and improvement of the resistance of the organism. The direct relationship between research on sleep and a wide range of problems of space medicine makes the latter important from both a theoretical and practical viewpoint. On this basis, we attempted to summarize the existing data on various problems of sleep and to formulate fundamental principles and investigation methods, relative to the problems and conditions of space flight.

The literature on sleep contains an immense amount of work in the form of individual papers and specialized monographs. This extensive clinical and experimental material, however, accumulated by the medical profession in this and other countries for the successful solution of astronautics problems, is still both methodologically and factually inadequate.

This inadequacy is due, on the one hand, to our insufficient knowledge of the mechanism of sleep and of the biological processes in the cells affected by inhibition of sleep, to the lack of reliable means for establishing normal sleep and wake patterns, inducing sleep in unfamiliar environment and unaccustomed posture, accompanied by modification of the customary cycle of diurnal activities, etc. and, on the other hand, to the specific nature of the routine work of astronauts, which involves stay in the enclosure of a cabin, effect of weight-

* Numbers in the margin indicate pagination in the foreign text.

lessness, noise and other flight factors on the organism, limitation of motor activity, etc.

In this paper we are presenting certain factual data relating to the characteristics of sleep under the influence of various space flight factors on human subjects (noise, angular rotation, isolation, etc.) together with materials on the differential diagnosis of states similar in external and electrophysiological manifestations (somnolent and precollaptoid state, fatigue phenomena).

We made a long series of studies (about 300) of the natural night sleep of healthy subjects ranging in age from 21 to 40 years, after clinical examination. The sleep studies were based on the combined recording of cycles of physiological indices (according to the principle of maximum significance), including data of clinical observations, objective and subjective evaluation of the quality of sleep, bioelectrical activity of the brain, motor activity of the sleeping subjects, and experimental study of the depth of sleep. /60

The technique of the experimental study of the depth of sleep is given in detail in the paper by V.I.Myasnikov and L.S.Chesalin (1966), with certain modifications in the program of presentation of auditory stimuli: instead of pure tones of the same frequency, we used acoustic signals in the sequence of 12,000, 11,000, 10,000 ..., 3000, 2000 cps. This presentation, in our opinion, provided the element of novelty (each successive signal being different from the preceding one) and an increase in loudness according to the subjective estimate.

Our studies showed that the respective factor, regardless of its modality, will lead to disturbances of the quality of sleep, manifesting themselves in irregularities of falling asleep and in a relatively superficial sleep with dreaming and frequent awakening without cause (in the opinion of the subject), especially during the first night of the experiment.

These disturbances were obviously connected with the reaction of the organism to the new environment, a reaction based on the mechanisms of the orientation reflex.

According to our data, during the waking hours (in experiments with prolonged isolation), this reaction manifested itself in some subjects in signs of general excitation, certain hastiness, fussiness, general nervousness, a state of mild agitation with corresponding changes in facial expression, voice intonation, etc. as well as in changes of the bioelectric activity of the brain (lowering of the α-rhythm index, increased duration and number of the sections of spontaneous depression), in modifications of the vegetative reactions (lability of pulse, spontaneous fluctuations of the skin-galvanic reflex) and in shifts of a number of biochemical indices (for example, increased excretion of 17-ketocorticosteroids in the urine, etc.).

We observed these manifestations in experiments on the action of various factors (noise, angular rotation, hypodynamia), in which the degree of reaction to the experimental environment was determined not only by the individual psychological personality traits but also by other circumstances (complexity

and duration of prior examination, subject's attitude toward it, transition through potential hazards, etc.). It is natural to suppose that the emotional stress induced by the unusual experimental environment must, of necessity, affect the quality of sleep. In some subjects, this manifested itself in difficulty in falling asleep, in a certain irritability, and in a more acute awareness of the surroundings (obviously uncomfortable posture, inadequate judgement of the hygienic conditions, increased motor activity, etc.). As a typical example of the disturbance of sleep, we will discuss a seven-day rotation test (angular velocity of 40°/sec). Despite the differing vestibular resistance of the subjects to rotation (the studies were conducted on two subjects at the same time), their sleep during the first night remained shallow, with repeated spontaneous awakening. The bioelectric activity of the brain was characterized by instability of the EEG, with portions of the crowded theta waves being replaced by an indeterminate rhythm of 15 - 20 μv amplitude. According to data by V.N.Nesterenko who participated in this work, this was accompanied by increased motor activity of the subjects. The number of movements under the experimental conditions increased by 48 - 84% from the initial level. It was noted that small movements lasting 0.05 - 0.1 min predominated in the motor activity. Motor activity of this nature (increase in total number of movements), on the one hand constitutes an objective expression of the disturbance of sleep due to the unfamiliar experimental environment and, on the other hand, has a protective character (prevalence of small movements) directed toward attenuating the effects of Coriolis accelerations as an adequate stimulus of the vestibular analysor. /61

The alleviating effect of sleep influenced the intensity of the vestibular-vegetative disturbances recalling rolling sickness. After sleep, the appetite was improved, the movements became freer, nausea and dizziness diminished or disappeared, etc. After prolonged rotation, the vestibular-vegetative disturbances, considerably attenuated after sleep, increased during the following day but without reaching the level of the preceding days and gradually died out as adaptation proceeded.

Without going into details of the estimation of the central mechanisms of the alleviating effect of sleep on the manifestations of vegetative disturbances during rotation, it should be stated that obviously the protective character of sleep is connected with the general restriction of motor activity (by comparison with the waking state) and the relaxed posture of the musculature as well as the lowered vestibular reactivity during sleep.

These results permitted the conclusion that the protective character of the mechanism of sleep finds its expression in a diminution of the functional reactions due to the effect of Coriolis acceleration. This conclusion is of practical importance, since sleep of sufficient depth and duration in actual flight will prevent vestibular-vegetative disturbances and a reduction in work capability of the astronauts.

This relationship between extent of functional disturbances and quality of sleep can be illustrated concisely on hand of data from an experiment with protracted exposure to broad-band noise (24 hrs) of 75 - 78 db intensity. In subjects with good sleep, the functional disturbances in the auditory analysor (masking thresholds*, auditory adaptation) decreased considerably, or dis-

* For footnote see following page.

appeared entirely, after sleep. In subjects who had slept well, a masking threshold, on the average 15 - 35 db lower, was observed in the morning hours, indicating restoration of the function of the auditory analysor during sleep. In subjects whose sleep, in their own opinion, had been superficial we noted an average rise of 15 - 30 db of the masking threshold. The same applies to auditory adaptation. In persons who had slept well, disturbance of the masking threshold and of the auditory adaptation decreased whereas, after poor sleep, these disturbances were not alleviated but, in certain cases, they actually increased. We attached particular importance to disturbances of adaptation since they permitted - to some extent - judging the functional state of the cortical division of the auditory analysor and of the cerebral cortex as a whole, during sleep. A detailed analysis of the disturbances of the masking threshold and of auditory adaptation, in collaboration with I.Ya.Yakovleva, O.P.Kozerenko et al., showed that the degree of disturbance of each was different (the adaptation was disturbed more than the masking threshold, in both magnitude and range. In the final analysis, this is connected with the nonuniform disturbance of the peripheral and central divisions of the auditory analysor, which proved to be more vulnerable on account of poor sleep. As a result of these disturbances, broadband noise ceased to be physiologically neutral and was perceived by the subject as broken up into individual frequency components, the effect of whose psychophysiological action has been repeatedly described in the literature. This /62 obviously explains the unpleasant sensations connected with the action of noise felt by the astronauts A.G.Nikolayev, V.V.Tereshkova, G.Cooper, and W.Conrad, in space flight and during rest (Yu.M.Volynkin et al.; Strughold et al.).

Sleep as a protective-adaptive reaction of the body was most pronounced under conditions of isolation. In particular, in some subjects, the beginning of somnolescence was noted during the periods of scheduled wakefulness, unconnected with active vigilance (for example, waiting for the recording of physiological functions). Thus, the study of sleep under the influence of various factors on the subject permitted formulation of certain general ideas as to its features: nonspecificity of the disturbance, positive effect on the restoration of functional shift and on capacity for work.

The data of ground experiments are directly related to the question of evaluating the sleep pattern of astronauts in flight (comparing them as a standard with telemetric data: ECG, EEG, EOG, respirometry, etc.), and, consequently, to the selection of the most informative indices. In our opinion, the most promising of these indices for the characterization of sleep of astronauts are the dynamics of the brain biopotentials and of the motor activity, the rate of cardiac contractions, and the results of televised observation. Comparison of these indices will enable specialists not only to make a qualitative evaluation of the depth and duration of sleep, but also eventually to solve another important problem directly connected with the medical supervision of the state of health of astronauts.

It is well known that the space flight factor as a whole (weightlessness, restricted motor activity, monotony of surroundings, etc.), in their effect on

---

* The masking threshold is the threshold of audibility for the action of an extraneous noise on the subjects.

the organism, lead to various functional shifts. Speaking of functional shifts, we cannot ignore the development of "difficult" states, which, being based on various physiological mechanisms, have an end effect rather close to the external clinical and electrophysiological manifestations. This question is important for differential diagnosis between somnolescent and precollaptoid states and between the drowsiness and manifestations of fatigue which may develop in flight owing to uniformity and monotony of the surroundings, necessity of maintaining a given posture for relatively long periods, and enforced hypokinesis, against the background of the considerably decreased effect of the gravitational factor.

The use, as a primary differential index, of the frequency of cardiac contractions worked-up by the method of variational pulsometry, permitted a differentiation between somnolescent and precollaptoid states (the latter was simulated by O.P.Kozerenko in ground experiments in tests involving prolonged orthostasis). Considering our data from this point of view, we found that during all stages of the orthostatic test, a constant variation of the activity of the regulatory mechanisms takes place, mostly under predominance of the sympathetic influence on the heart beat (if toleration of the test is good).

In development of precollaptoid states (collapse) the slope of the variational curves is characterized by inadequate changes in the curve parameters: for example, a leftward shift of the curve is accompanied by broadening and a rightward shift by narrowing, which indicates a disturbance of the function of cardiac automatism. This was expressed graphically by a leftward shift of the variational curve of frequency of cardiac contractions and by its narrowing. On falling aslepp, a distinct rightward shift and broadening of this curve was noted, indicating the predominance of parasympathetic regulation.

Prolonged maintenance of a forced posture, activity under monotonous /63
circumstances, together with development of precollaptoid states, may lead to manifestations of fatigue and to a state of the central nervous system which has not yet been completely defined - probably a lowering of cortical tonus (P.S. Kupalov). The necessity of differential diagnosis between drowsiness and fatigue is dictated by the fact that, whereas somnolescent states, which are not dangerous to health, can affect only the quality of the work to be done, true fatigue requires special prophylactic measures and sometimes even organizational measures.

According to observational data and as indicated by the EEG, there was considerable similarity between the somnolescent state and the manifestation of fatigue. Bearing in mind the necessity of differentiating between these conditions, we made a detailed clinical and mathematical analysis in collaboration with F.D.Gorbov. As our primary criterion (according to reliable data) we used the characteristic of the dynamics of trace reactions, in particular the rise of the peaks of the α-rhythm in response to withdrawal of the optical stimulus. We found that the resultant stagnating character of the heightening of the α-rhythm (i.e., the discontinuous action only of the following stimulus) against the background of diffuse slow waves and lowered amplitude of the biopotentials of the brain on the original EEG curve was a reliable sign of fatigue. On the other hand, characteristic of the somnolescent state in the subjects were the brief excursions, lasting not more than 10 sec, of the synchronized and exalted

α-rhythm. This was also indicated by the fact that the flashes of exaltation of the α-rhythm in the subjects appeared only after repeated presentation of a light stimulus.

We have discussed here only a few questions related to the disturbance of sleep under the action of various extremal factors of space flight, and the significance of the data for differential diagnosis, etc. However, this merely forms a part of a larger problem and constitutes a first attempt at generalizing the data on sleep obtained in experiments simulating the conditions of space flight with respect to a number of hygienic and physiological parameters.

REFERENCES

1. Volynkin, Yu.M. et al.: The First Group Space Flight (Pervyy gruppovoy kosmicheskiy polet). Moscow, 1964.
2. Volynkin, Yu.M. et al.: The Second Group Space Flight (Vtoroy gruppovoy kosmicheskiy polet). Moscow, 1965.
3. Kupalov, P.S.: Byull. Eksperim. Biol. i Med., Vol.26, No.9, p.237, 1948.
4. Myasnikov, V.I. and Chesalin, L.S.: Vopr. Psikhol., No.3, p.174, 1966.
5. Strughold, H.: Ann. N.Y. Acad. Sci., Vol.134, p.413, 1965.

Translated for the National Aeronautics and Space Administration by the O.W.Leibiger Research Laboratories, Inc.